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A potential of Pt-based honeycomb catalyst usage during the pistachio shell combustion

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Aim of the study

- **Aim of the study:** Determination of possibilities of combustion and co-combustion of pistachio shells with standard wooden pellets in real automatic small combustion equipment, used for direct household heating.
- **The novelty of the study:** Description of the data obtained by real combustion tests of previously unexplored material for mentioned purposes, newly considered as very valuable fuel for small-scale combustion equipment in combination with oxidizing honeycomb catalyst.
- **Applicability:** Obtained data will be beneficial for pistachio producers, pistachio consumers with small combustion equipment for pellet combustion as well as for small combustion equipment manufacturers.

Research motivation

- Increasing trend of energy pricing (including pellets).
- Increasing trend of the number of local heating appliances with automatic fuel supply in central Europe → increasing demand for pellets.
- Restrictions on the import of pellets from Russia (2.4 million tonnes).
- Increasing trend of pistachio production.
- Similar technical and chemical parameters of pistachio shells in comparison to wooden pellets.
- No additional treatment is necessary after the separation of the shell from the core (drying, crushing, pelletizing).

Fuel

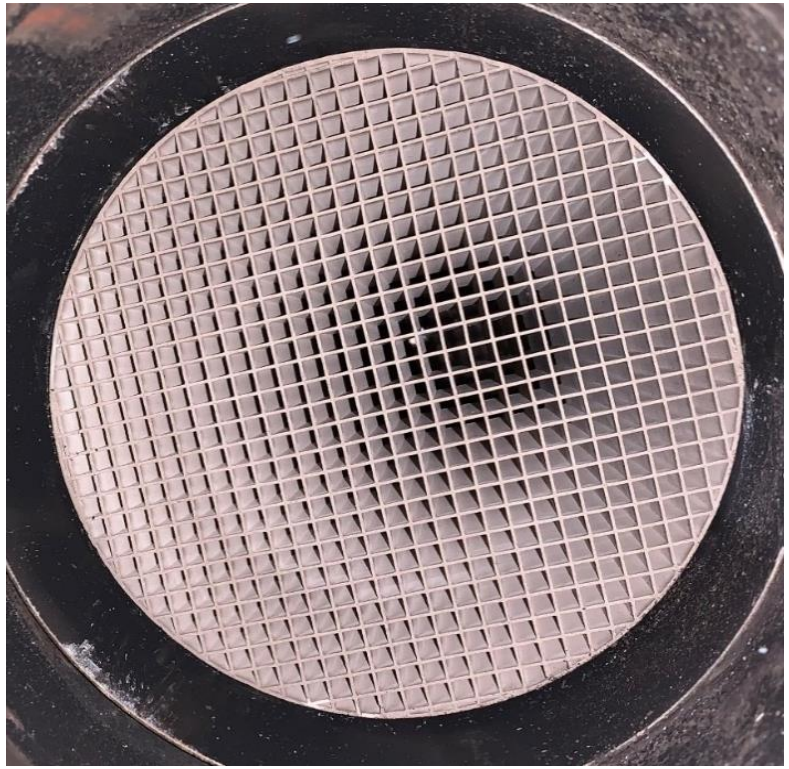
	Abbreviation	Unit	Pellets	Pistachio shells
Lower heating value	LHV	$MJ \cdot kg^{-1}$	17.02	16.00
Volatile matter in combustibles	V^{daf}	$\%_{wt}$	84.06	83.96
Carbon	C^{r}	$\%_{wt}$	46.17	43.85
Hydrogen	H^{r}	$\%_{wt}$	5.37	5.38
Nitrogen	N^{r}	$\%_{wt}$	< 0.20	< 0.20
Oxygen	O^{r}	$\%_{wt}$	38.87	40.94
Sulphur	S^{r}	$\%_{wt}$	< 0.02	0.02
Water	W^{r}	$\%_{wt}$	8.58	8.64
Ash	A^{r}	$\%_{wt}$	0.79	0.97
Bulk density	BD	$g \cdot dm^{-3}$	662.5	286.9

Fuel

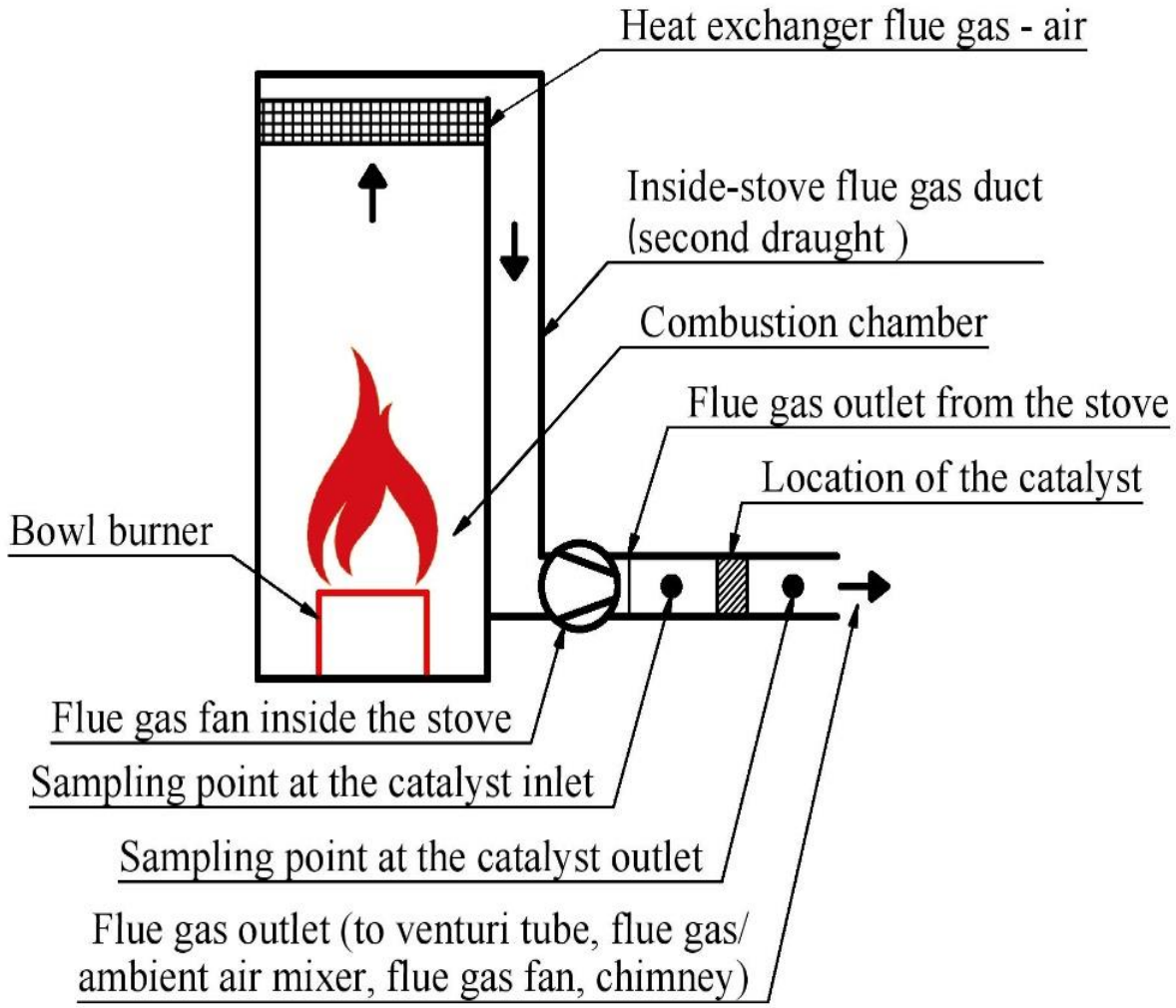
Mixture number [-]	Pellets [$\%_{wt}$]	Pistachio shells [$\%_{wt}$]	Bulk density [$g \cdot dm^{-3}$]	LHV [$MJ \cdot kg^{-1}$]
1	100	0	662.5	17.02
2	90	10	610.7	16.92
3	75	25	525.4	16.77
4	50	50	419.7	16.51
5	25	75	352.7	16.26
6	0	100	286.9	16.00

Catalyst

Parameter	Abbreviation	Unit	
Body material	-	-	cordierite substrate
Type of coating	-	-	sol-gel coating
Active element(s)	-	-	platinum
Active elements loading	D_{load}	$g \cdot m^{-3}$	317
Inlet surface area	A_{in}	m^2	0.016285536
Height	H	m	0.05
Coated area of carrier	A_{cat}	m^2	0.56373
Cell density	CD	$cells/cm^2$	4.14



Combustion equipment



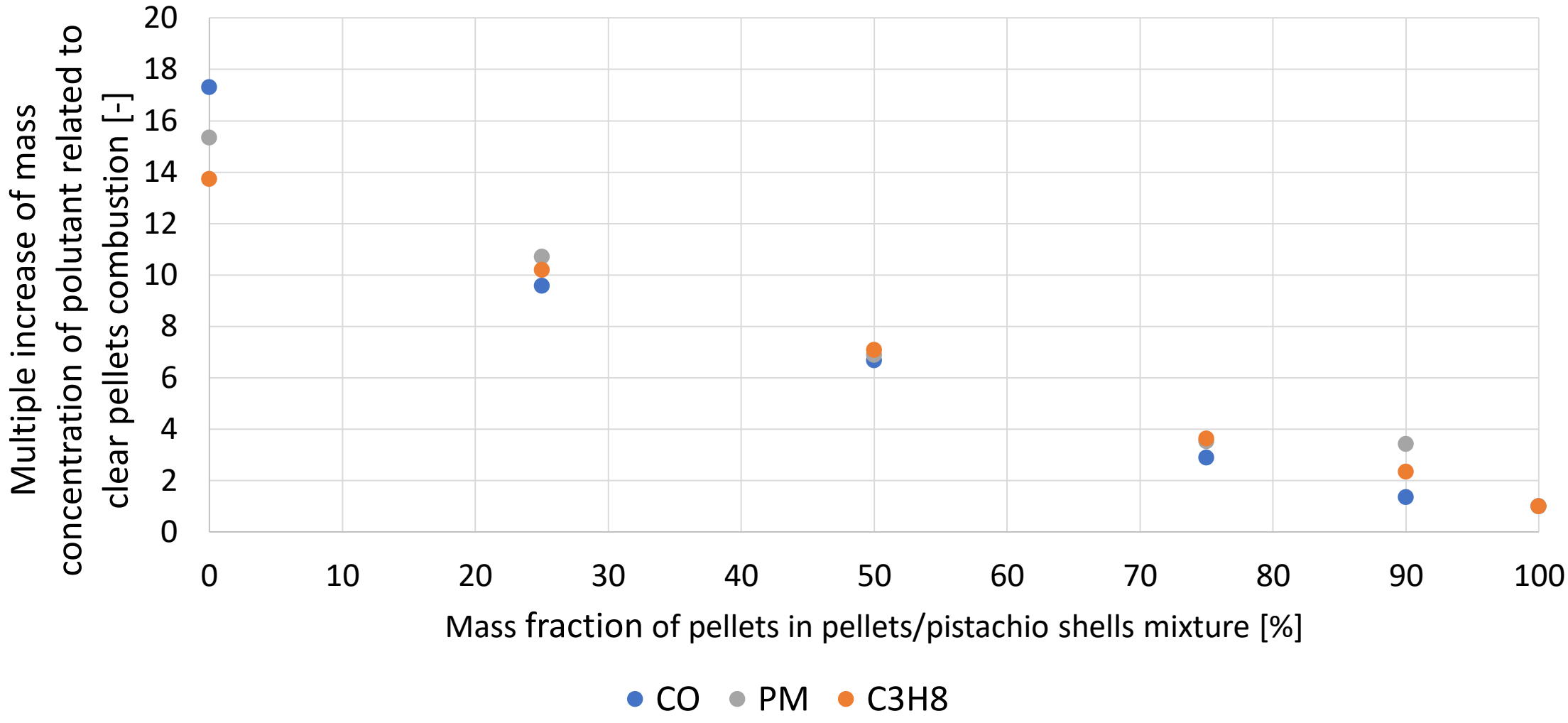
Results

- No technical problem occurred during the combustion of all fuel mixtures (sintering, high amount of the unburned carbon in the ash, etc.).
- To maintain the heat output of the stove during the fuel mixtures combustion, the setting of the fuel feeder had to be changed due to the lower bulk density of the pistachio shells.
- Significant increase in the mass concentration of CO, C_3H_8 and PM was observed with the increase of the pistachio shell mass fraction in the fuel with obvious dependency between these two parameters.
- Described type of catalyst proved to be very efficient for decrease of mass concetration CO and partialy efficient for decrease mass concentraton of C_3H_8 in flue gas temperature above 250 °C and mass concentration of CO at the catalyst inlet below 1,500 mg/m^3.

Results

Fuel mixture		pellets/ pistachio shells	100/0	90/10	75/25	50/50	25/75	0/100
Heat input to the stove		kW	5.7	5.6	5.7	5.7	5.4	5.4
Mass flow of the fuel to the burner		$kg \cdot h^{-1}$	1.21	1.19	1.23	1.23	1.21	1.22
GHSV (STP conditions)		hod^{-1}	32 026	32 267	32 684	35 505	33 340	31 698
Flue gas temperature		°C	257	253	260	255	241	225
The volume fraction of O_2 in dry flue gas at the catalyst inlet		%	15.7	15.6	15.2	15.8	16.0	16.1
Reference volume fraction of oxygen		%	13	13	13	13	13	13
Mass concentration of pollutants in dry flue gas at reference volume fraction of oxygen (at the catalyst inlet)	CO	mg/m^3_N	513	691	1 475	3 421	4 905	8 871
	NO_X	mg/m^3_N	95	87	125	130	143	134
	C_3H_8	mg/m^3_N	7	16	25	49	71	95
	PM	mg/m^3_N	nd	nd	nd	nd	nd	nd
	CO_2	g/m^3_N	149	148	149	149	148	145
Mass concentration of pollutants in dry flue gas at reference volume fraction of oxygen (at the catalyst outlet)	CO	mg/m^3_N	193	364	839	2 683	4 368	8 652
	NO_X	mg/m^3_N	88	81	117	125	139	137
	C_3H_8	mg/m^3_N	6	12	21	39	63	86
	PM	mg/m^3_N	89	303	313	611	952	1 364
	CO_2	g/m^3_N	150	148	152	148	149	146
CO conversion rate by catalyst		%	62.3	47.3	43.1	21.6	10.9	2.5
C_3H_8 conversion rate by catalyst		%	12.7	25.9	16.8	21.5	10.7	9.6

Results


Multiple increase of mass concentration of polutant related to clear pellets combustion [-]
20
18
16
14
12
10
8
6
4
2
0
0
10
20
30
40
50
60
70
80
90
100
Mass fraction of pellets in pellets/pistachio shells mixture [%]
CO
PM
C3H8

Conclusions

- Pistachio shells can partially substitute wood pellets in small combustion equipment.
- Mass concentration of CO and C_3H_8 in the flue gas at the catalyst outlet would be at the same level during the combustion of pellets with 12% (CO) and 2% (C_3H_8) of pistachio shells as during the combustion of the pure pellets for selected kind of stove. The influence of the catalyst on the mass concentration of PM was not observed.
- Influence of the mentioned fuel mixtures on the flue gas composition for different kinds of pellet burners (gutter burner, retort burner, rotation burner) should be further observed.

Thank you for your attention

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